

European Spine Journal

Variations in Arterial Supply to the Lower Lumbar Spine

--Manuscript Draft--

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| Manuscript Number: | |
| Full Title: | Variations in Arterial Supply to the Lower Lumbar Spine |
| Article Type: | Original Article |
| Keywords: | Vascular anatomy; Lower lumbar spine; Variation |
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| Funding Information: | JSPS KAKENHI Grant Number 25462294 Dr. Toshinori Sakai |
| Abstract: | <p>Purpose Several papers examined the vascular anatomy of the lumbosacral region using cadavers with angiography. However, few reports used CT angiography, and discussion on variations of fourth lumbar, fifth lumbar, and lumbar branch of iliolumbar arteries were limited. To clarify the vascular variations around the lower lumbar spine including the lumbosacral region, particularly at the posterior elements, we performed anatomical analysis using computed tomography (CT).</p> <p>Methods Extra-osseous arteries surrounding the lumbar spine including the lumbosacral region were evaluated by two orthopedic surgeons independently, using 323 consecutive abdominal contrast-enhanced multi-planar CT scans that were taken for surgical plans in colon cancer patients. Subjects were 204 men and 119 women, whose ages ranged from 15 to 89 years (mean: 66.5).</p> <p>Results Each segmental artery was visible at the L1-L4 spinal levels, running from the vertebra through the lamina in >90% patients (right: 91.0%;left: 90.7%), while it was visible in <10% patients at the L5 level (right: 4.6%; left: 8.7%). The extra-osseous arterial supply to the L5 lamina was basically provided by two vessels on each side. One was mostly derived from the L4 segmental artery (right: 92.6%; left: 92.0%) that was distributed around the superior articular process, the other was derived from the iliolumbar artery</p> |

(right: 62.9%; left: 55.7%) that was distributed around the inferior articular process through the lamina. There were mainly four combination patterns of those arteries. These combinations, which had been considered as regular patterns in textbooks, were observed in approximately 50% (right: 55.7%; left: 48.6%) of patients.

Conclusion

Various distributions of arteries around the lower spine were identified.

1 **Variations in Arterial Supply to the Lower Lumbar Spine**

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3 1 **Variations in Arterial Supply to the Lower Lumbar Spine**
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2 **1 Abstract**

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5 **2 Purpose**

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3 Several papers examined the vascular anatomy of the lumbosacral region using cadavers
4 with angiography. However, few reports used CT angiography, and discussion on
5 variations of fourth lumbar, fifth lumbar, and lumbar branch of iliolumbar arteries were
6 limited. To clarify the vascular variations around the lower lumbar spine including the
7 lumbosacral region, particularly at the posterior elements, we performed anatomical
8 analysis using computed tomography (CT).

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10 **Methods**

11 Extra-osseous arteries surrounding the lumbar spine including the lumbosacral region
12 were evaluated by two orthopedic surgeons independently, using 323 consecutive
13 abdominal contrast-enhanced multi-planner CT scans that were taken for surgical plans
14 in colon cancer patients. Subjects were 204 men and 119 women, whose ages ranged
15 from 15 to 89 years (mean: 66.5).

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17 **Results**

18 Each segmental artery was visible at the L1–L4 spinal levels, running from the vertebra
19 through the lamina in >90% patients (right: 91.0%;left: 90.7%), while it was visible in
20 <10% patients at the L5 level (right: 4.6%; left: 8.7%). The extra-osseous arterial supply
21 to the L5 lamina was basically provided by two vessels on each side. One was mostly
22 derived from the L4 segmental artery (right: 92.6%; left: 92.0%) that was distributed

1 around the superior articular process, the other was derived from the iliolumbar artery
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5 1 around the superior articular process, the other was derived from the iliolumbar artery
6 (right: 62.9%; left: 55.7%) that was distributed around the inferior articular process
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8 2 (right: 62.9%; left: 55.7%) that was distributed around the inferior articular process
9 through the lamina. There were mainly four combination patterns of those arteries.
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11 3 through the lamina. There were mainly four combination patterns of those arteries.
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13 4 These combinations, which had been considered as regular patterns in textbooks, were
14 observed in approximately 50% (right: 55.7%; left: 48.6%) of patients.
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16 5 observed in approximately 50% (right: 55.7%; left: 48.6%) of patients.
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7 *Conclusion*

8 Various distributions of arteries around the lower spine were identified.

10 **Keywords:** Vascular anatomy, Lower lumbar spine, Variation

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3 **1 Introduction**
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7 2 Recently, minimally invasive spinal surgeries such as percutaneous endoscopic lumbar
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10 3 discectomy (PELD) and extreme lateral interbody fusion (XLIF) have been developed
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14 4 [1-4]. They can be performed with minimal disruption of the spinal structures including
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17 5 ligaments and muscles, but these minimal approaches sometimes lead to critical
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21 6 complications such as vascular injury due to limited visualization and lack of
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24 7 knowledge [5,6]. Therefore, we should know anatomical structures in detail,
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28 8 particularly the spinal vasculature.
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32 9 Detailed vascular anatomy in the lumbar region has been scarcely reported,
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35 10 especially the lumbosacral region [7]. With regard to segmental arteries, they have been
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39 11 described as paired direct branches of the aorta from T2 to L4, but only the L5
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42 12 segmental artery is considered to bifurcate from the median sacral artery [8, 9]. In
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46 13 established textbooks, there are some intriguing statements about the peculiarities of the
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49 14 arterial system in the lumbosacral region [10]. However, anatomic data concerning the
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53 15 lumbar arterial system has been scant. Although anatomical studies using angiography
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56 16 of the lumbar spine in cadaveric and living subjects have been reported, the number of
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1 subjects was limited [7].

2 The purpose of this study was to clarify the artery variations around the lower
3 lumbar spine, including the lumbosacral region.

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3 **1 Materials and Methods**
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7 2 We retrospectively reviewed the contrast-enhanced multi-planner abdominal computed
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10 3 tomography (CT) scans of 323 consecutive subjects (204 men and 119 women), whose
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14 4 ages ranged from 15 to 89 years (mean: 66.5). All CT scans were performed for the
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17 5 purpose of creating surgical plans for colon cancer patients in our hospital from April,
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21 6 2009 through March, 2013. Subjects with a past medical history of lumbar surgery were
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24 7 excluded. The first scan was examined in those who had undergone repeated CT scans
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27 8 within the observation period. Using Aquarius NET[®] Server (TeraRecon, Inc.; San
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31 9 Mateo, CA) to reconstruct CT images, extra-osseous arterial variations surrounding the
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35 10 lower lumbar spine including the lumbosacral region were reviewed by two orthopedic
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38 11 surgeons. Differing opinions were resolved by consensus. We assessed the position of
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42 12 the aortic bifurcation according to the spinal level, lumbar segmental artery, median
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45 13 sacral artery, anatomical patterns of the extra-osseous arteries supplying the posterior
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49 14 element of L5 using the methods described below. In this study, L5 was considered the
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53 15 lowest mobile spine.
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3 1 *Aortic bifurcation*
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7 2 The position of the aortic bifurcation was assessed according to the spinal level using
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10 3 multi-planar reconstruction (MPR) of the CT scans of the lumbar spine. The spinal level
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13 4 was defined as a unit including the vertebra and cranial disc space. For example, the L4
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16 5 level was defined as the L3–4 intervertebral disc space and L4 vertebral body (Figure
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28 8 *Segmental arteries*
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31 9 We assessed the presence of segmental arteries between L1 and L5 on both sides using
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34 10 the MPR images of the CT scans and the reconstructed three-dimensional (3D)-CT
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37 11 images (Figure 2).
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45 13 *Median sacral artery*
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48 14 The presence of this artery was assessed using axial CT scans.
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56 16 *Distributing arteries supplying the posterior element of L5*
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3 1 It was observed that the extra-osseous vascular supply for the L5 lamina was provided
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7 2 by two arteries from the cranial and caudal sides. One artery was mostly derived from
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10 3 the cranial side that was distributed around the superior articular process, and the other
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14 4 was derived from the caudal side that was distributed around the inferior articular
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17 5 process through the lamina. The distribution of these arteries to the posterior element
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21 6 was confirmed using the MPR images and reconstructed 3D-CT images of the lumbar
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25 7 spine as much as possible. In addition, we assessed the combinations of the two arteries
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28 8 as the vascular supply to the posterior element of L5.
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1 **Results**

2 *Aortic bifurcation*

3 The position of the aortic bifurcation according to the spinal level was found at L3 in 4
5 subjects (1.2%), L4 in 166 (51.4%), and L5 in 153 (47.4%) (Table 1).

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7 *Segmental arteries*

8 Between L1 and L4, each segmental artery was identified, running from the vertebra
9 through the lamina, in more than 90% of subjects (right: 91.0%; left: 90.7%) (Figure 3A
10 and Table 2). In contrast, the fifth lumbar segmental artery was identified in less than
11 10% patients (right: 4.6%; left: 8.7%) (Figure 3B). It mostly branched from the median
12 sacral artery and ended at the anterolateral part of the fifth lumbar vertebra.

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14 *Median sacral artery*

15 The median sacral artery was present in 297 patients (92.0%) among all subjects, which
16 is derived from the aortic bifurcation (Table 2).

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1 *Distributing arteries for the posterior element of L5*

2 *1) For the superior articular process of L5 (Table 3)*

3 In most subjects (right: 92.6%; left: 92.0%), branches of the L4 segmental artery were
4 distributed around the superior articular process (Figure 4A–C).

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6 *2) For the inferior articular process of L5 (Table 3)*

7 In more than half of the subjects (right: 62.9%; left: 55.7%), branches of the iliolumbar
8 artery were distributed around the inferior articular process through the lamina (Figure
9 4A, D). However, in other subjects, several variations of the distributing vasculature
10 were identified.

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12 *3) Combination of those two arteries*

13 There were mainly four patterns of vascular supply to the posterior element of L5
14 involving the combination of the two arteries (Figure 4, Table 4). Approximately 50%
15 (right: 55.5%; left: 48.6%) of subjects had a regular pattern of vascular supply to the

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- 1 posterior elements as per textbook description: the cranial side is supplied by the L4
- 2 segmental artery and the caudal side is supplied by the iliolumbar artery.
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3 **1 Discussion**
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7 2 Reports describing the lumbar segmental arteries, particularly focusing on the branches
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10 3 that distribute to the posterior element of the lower lumbar spine, have been limited. In
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14 4 this study, the notable findings are as follows. First, the aortic bifurcation varied from
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17 5 L3 to L5 depending on the subjects. Second, from L1 to L4, each segmental artery was
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21 6 identified bilaterally in more than 90% of subjects, but it was identified in less than 10%
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24 7 of patients at L5. Third, four main patterns of vascular supply to the posterior element
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28 8 of L5 by the two arteries were identified, and approximately 50% of subjects had a
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32 9 regular vascular pattern as described in the textbook.
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38 11 *Aortic bifurcation*
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42 12 In this study, the aortic bifurcation was found at L4 in 51.4% of subjects, and
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45 13 at L5 in 47.4% of subjects. These results are similar to those in the cadaver study by
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49 14 Pirro et al., who found the aortic bifurcation at the L4 and L5 vertebrae in 50% and 39%
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53 15 of subjects, respectively [11]. However, the location of the major vessels have been
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56 16 reported to vary according to the subjects' posture. Vaccaro et al. analyzed the spinal
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1 levels of the aortic bifurcation and confluence of the common iliac veins using supine
 2 and prone magnetic resonance imaging, and they reported that the aortic bifurcation was
 3 identified at L4 in 73% and 60% of subjects in the supine and prone positions,
 4 respectively [12].

5
 6 *Median sacral artery*

7 In a past cadaveric study, the median sacral artery was identified in 100% of
 8 cases (37 of 37) [13]. However, in our data using contrast-enhanced CT images, the
 9 artery was found in 92.0% (297/323). This discrepancy may be due to the difference in
 10 the method of identifying the artery; it may be present but invisible.

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 12 *Distributing arteries for the posterior element of L5*

13 It is well known that T2–L4 segmental arteries are direct branches of the aorta,
 14 and the L5 segmental artery bifurcate from the median sacral artery [7]. However, in
 15 this study, L1–L4 segmental arteries were identified traveling from the vertebra through
 16 the lamina in more than 90% of subjects, but the L5 segmental artery was identified in

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1 less than 10% of patients. In addition, various vascular patterns around the lower lumbar
 2 spine were found. Focusing on the posterior elements of L5, approximately 50% (right:
 3 55.5%; left: 48.6%) of subjects had regular vascular patterns that matched those in old
 4 textbooks [10]. The most frequent pattern of supply to the L5 posterior elements was the
 5 combination of the branches of the L4 segmental artery and the spinal branches of the
 6 iliolumbar artery. Even in cases where the L5 segmental artery was identified, it had a
 7 very small diameter compared with those at the other levels, and it was not identified in
 8 the posterior half of the L5 vertebra.

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 10 *To avoid vascular injury during surgery*

11 New, minimally invasive surgical procedures for the spine such as PELD and
 12 XLIF have been adopted for various lumbar disorders [1-4]. Although these procedures
 13 are less invasive, they sometimes lead to critical complications such as vascular injury
 14 due to limited visualization and lack of knowledge [5, 6]. Injuries of the lumbar
 15 segmental artery during surgical procedures are rare but have been documented in
 16 reports [5, 14]. Ahn et al. reported approximately 1% incidence of retroperitoneal

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3 1 hematoma following PELD via the transforaminal approach [5]. All cases of hematoma
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7 2 were associated with the L4–5 level. Retroperitoneal hematoma following XLIF has
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10 3 also been reported [14].
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14 4 According to the results of this study, several variations of distributing arteries
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17 5 from the lumbar segmental artery to the posterior element of L4–5 were identified and
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21 6 some branches traveled on the ventral side of the transverse process of L5 (Figure 4).
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24 7 This location corresponds to the entry point of the endoscope for PELD² and placement
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28 8 of the shim to stabilize the retractor for XLIF (Figure 5) [5]. Spine surgeons must know
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32 9 these anatomical structures and take care to avoid vascular injury during lumbar
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35 10 surgeries.
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42 12 *Limitations in this study*
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46 13 We fully acknowledge that there are limitations in this study. As 0.5-mm
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49 14 slices were taken, arteries with a diameter less than 0.5 mm may not be visualized. In
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53 15 addition, the ages of the subjects ranged from 15 to 89 years in this cross-sectional study.
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56 16 Elderly people are known to have sclerotic changes in the major arteries that may affect
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1 the distribution of those arteries. Despite these limitations, spine surgeons should know
2 about the results of this study.

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3 **1 Conclusion**
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7 2 Various distributions of arteries around the lower spine were identified. The aortic
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10 3 bifurcation varied from L3 to L5 depending on the subjects. From L1 to L4, each
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14 4 segmental artery was identified bilaterally in most subjects, but it was identified in less
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17 5 than 10% of patients at L5. Four main patterns of vascular supply to the posterior
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21 6 element of L5 by the two arteries were identified, and approximately 50% of subjects
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25 7 had a regular vascular pattern as described in textbooks. We hope these results will be
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28 8 helpful to avoid critical complications in lumbar surgeries.
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35 **10 Acknowledgement**
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38 11 This work was supported by JSPS KAKENHI Grant Number 25462294.
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45 **13 Conflict of interest**
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49 14 All authors confirm that there are no conflicts of interest with people or organizations
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53 15 that could bias this report.
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4 **1 Figure Legends**
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7 **2 Figure 1**
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10 3 The spinal level of the aortic bifurcation was defined as a unit including the vertebra
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14 4 and the cranial disc space on computed tomography (CT) of the lumbar spine. For
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17 5 example, the L4 level is above a black dotted line that is between the white lines in the
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21 6 sagittal view, where both common iliac arteries are seen between the L3–4
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25 7 intervertebral disc space and L4 vertebral body.
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31 **9 Figure 2**
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35 10 Between L1 and L5, we assessed the presence of segmental arteries on both sides using
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39 11 the multi-planar reconstruction CT images and the reconstructed three-dimensional
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42 12 (3D)-CT images.
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45 13 A: Coronal view of the lumbar spine shows two pairs of segmental arteries beside each
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49 14 vertebra. B: It is easier to understand their distributions in the reconstructed 3D-CT
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53 15 image (left aspect of the lumbar spine).
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1 **Figure 3**

2 A: Between L1 and L4, each segmental artery running from the vertebra through the
3 posterior elements was identified. However, the fifth lumbar segmental artery could not
4 be identified. B: Between L1 and L5, all segmental arteries running from the vertebra
5 through the posterior elements were identified.

6
7 **Figure 4**

8 Schemes of distributing arteries for the posterior element of L5. The artery from the
9 cranial side above the L5 transverse process distributes branches around the superior
10 articular process, and the artery from the caudal side below the L5 transverse process
11 distributes branches around the inferior articular process through the lamina. There are
12 mainly four variations as follows:
13 A) combination of L4 segmental artery and iliolumbar artery; B) L4 segmental artery
14 only; C) combination of L4 segmental artery and L5 segmental artery; and D)
15 combination of L3 segmental artery and iliolumbar artery.

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1 **Figure 5**

2 In this illustrated case, the L4 segmental artery has a descending branch on the ventral
3 side of the transverse process of L5, which is the pattern in Figure 4B. Sometimes, a
4 large-diameter branch was identified.

5

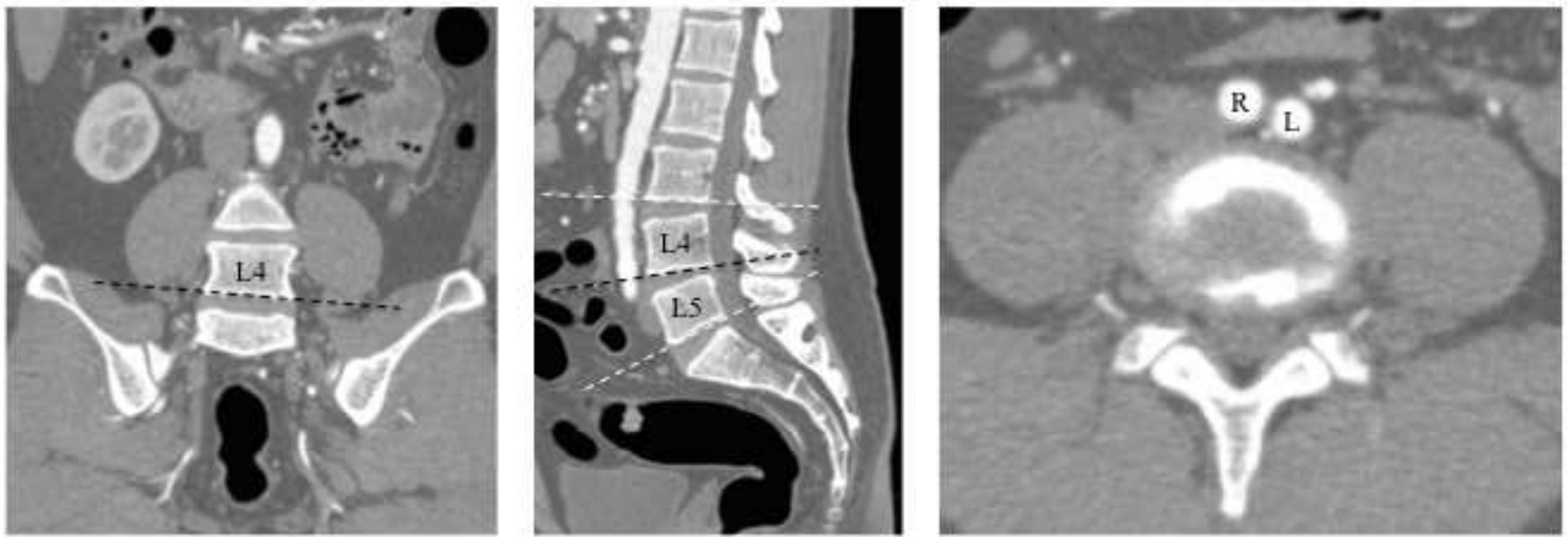


Figure 1

Figure 2

[Click here to download Figure: renamed_ea21b.tiff](#)



Figure 2

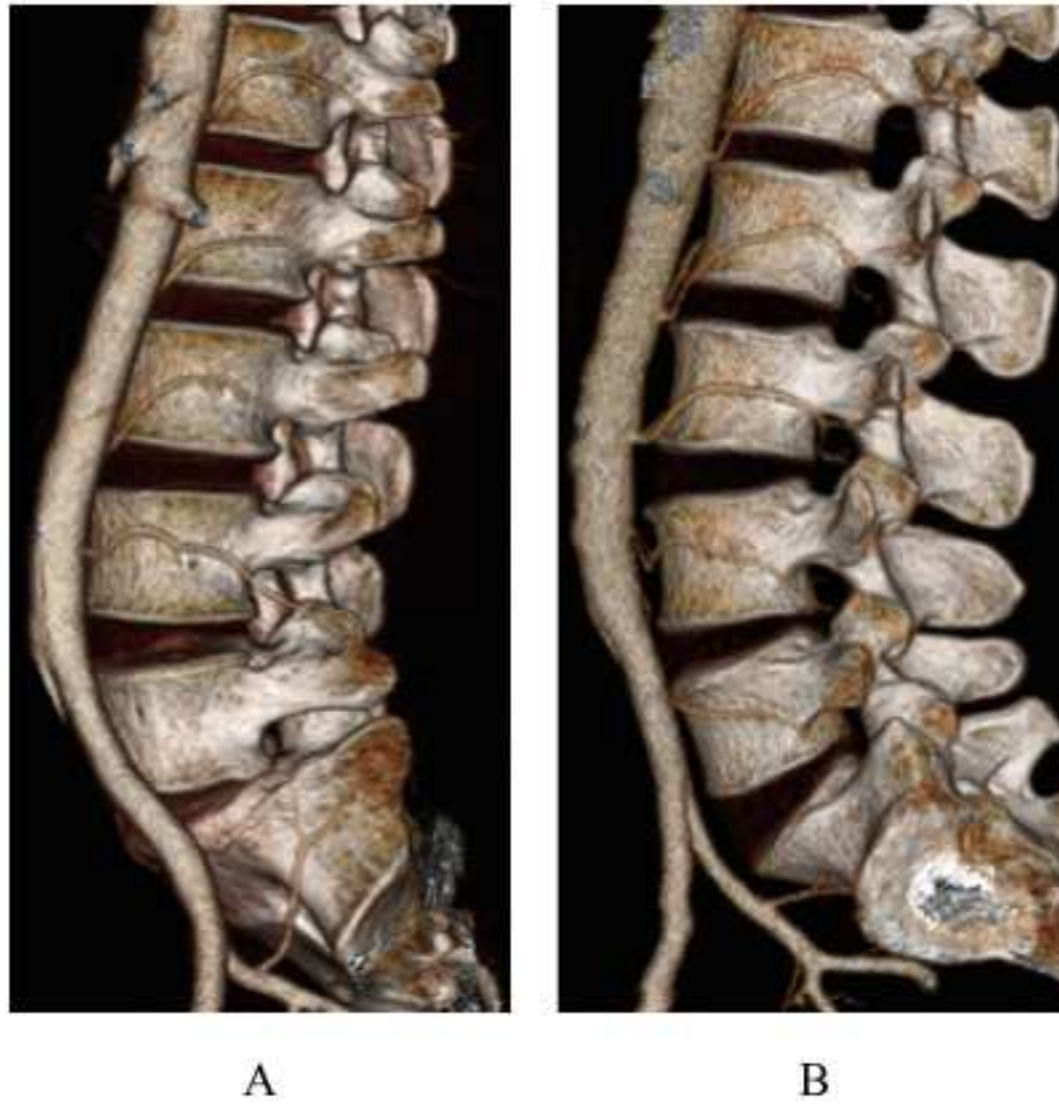


Figure 3

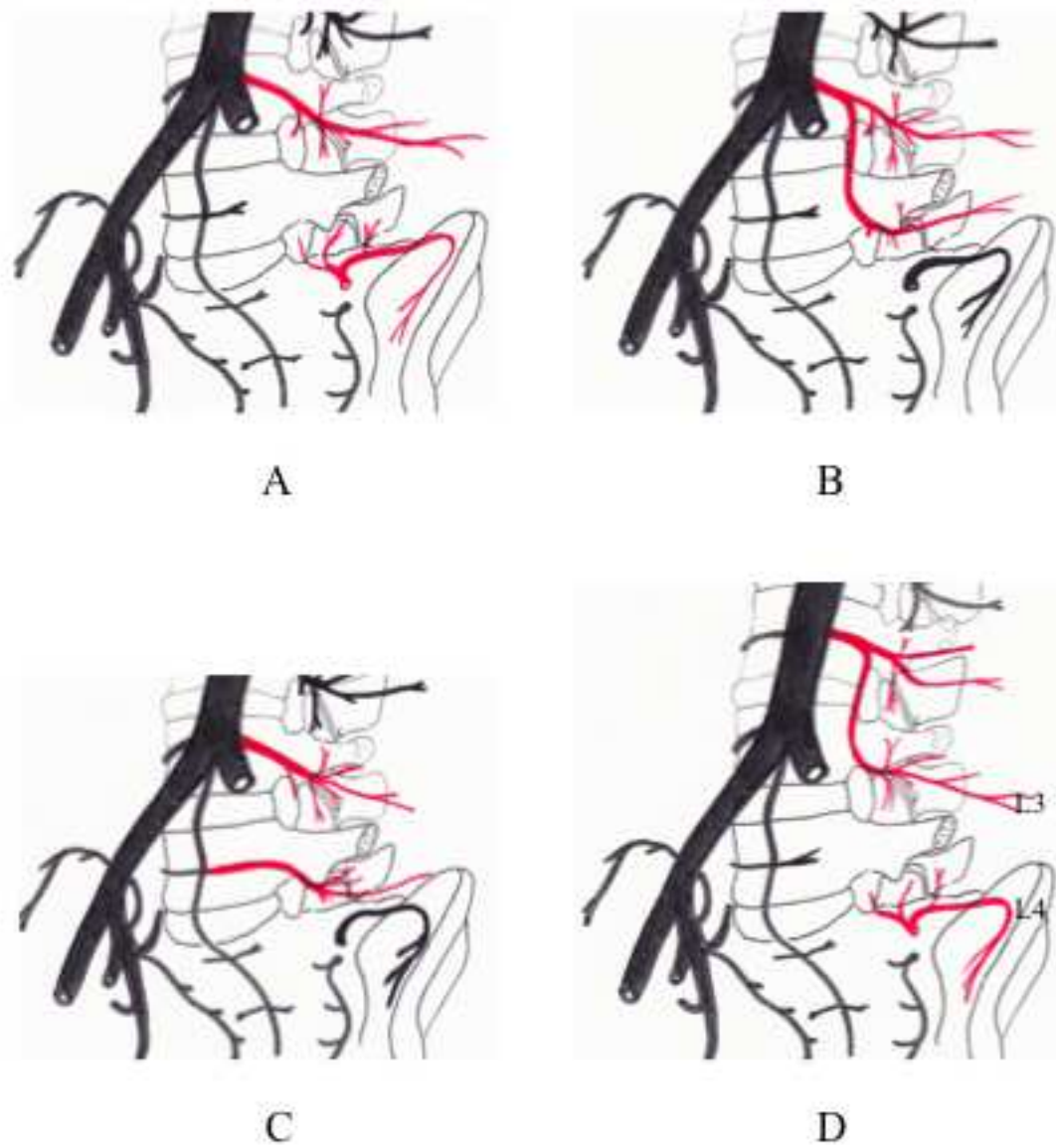


Figure 4

Figure 5

[Click here to download Figure: renamed_fb993.tiff](#)



Figure 5

Table 1 Spinal level of the aortic bifurcation

| Spinal level | n (%) |
|--------------|------------|
| L3 | 4 (1.2) |
| L4 | 166 (51.4) |
| L5 | 153 (47.4) |
| Total | 323 (100) |

Table 2 Identified arteries

| | | n (%) |
|-------------------------------|-------|------------|
| Segmental arteries (L1 to L4) | Right | 294 (91.0) |
| | Left | 293 (90.7) |
| Segmental arteries (L5) | Right | 15 (4.6) |
| | Left | 28 (8.7) |
| Median sacral artery | | 297 (92.0) |

Table 3 Distributing arteries to the posterior element of L5

| | Superior articular process | | Inferior articular process | |
|-----------|----------------------------|------------|----------------------------|------------|
| | Right | Left | Right | Left |
| L3SA | 20 (6.2) | 22 (6.8) | 1 (0.3) | 3 (0.9) |
| L4SA | 299 (92.6) | 297 (92.0) | 74 (23.9) | 83 (25.7) |
| L5SA | 0 (0) | 0 (0) | 11 (3.4) | 25 (7.7) |
| ILA | 4 (0.1) | 3 (0.9) | 203 (62.9) | 180 (55.7) |
| Other | 0 (0) | 0 (0) | 0 (0) | 31 (9.6) |
| Invisible | 0 (0) | 1 (0.3) | 34 (10.5) | 1 (0.3) |
| Total | 323 (100) | 323 (100) | 323 (100) | 323 (100) |

SA: segmental artery, ILA: iliolumbar artery

Table 4 Combinations of arteries distributing to the posterior element of L5

| Superior / Inferior | Right | Left |
|---------------------|------------|------------|
| L4SA / ILA | 180 (55.7) | 157 (48.6) |
| L4SA / L4SA | 74 (22.9) | 83 (25.7) |
| L4SA / L5SA | 11 (3.4) | 25 (7.7) |
| L3SA / ILA | 19 (5.9) | 19 (5.9) |
| Others | 39 (12.1) | 39 (12.1) |
| Total | 323 (100) | 323 (100) |

SA: segmental artery, ILA: iliolumbar artery